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J. H. JEANS: PROBLEMS OF COSMOGONY AND
STELLAR DYNAMICS. CAMBRIDGE, 1919;
A REVIEW

BY GUSTAF STRÖMBERG

In an essay with the above title the well-known English mathematician, J. H. Jeans, has published an investigation of the stability of rotating gaseous masses and, from a purely theoretical study of this problem, has arrived at conclusions which are very important in the study of stellar dynamics and the evolution of the stars.

The main part of the book contains an extensive mathematical study of the evolution of configurations for a rotating and gravitating gaseous mass, dealing especially with the stability of the different configurations. It is an extension of the work by Laplace, Roche, Jacobi, Lord Kelvin, Poincaré, and Darwin, giving at the same time a resumé of what has been done previously in this line of research.

Four simplified models of astronomical matter have been studied:

A. The incompressible model, consisting of a mass of homogeneous, incompressible matter of uniform density.

B. Roche's model, consisting of a point nucleus of great density, surrounded by an atmosphere of negligible density.

C. The generalized Roche model, consisting of a homogeneous, incompressible mass of finite size and of finite density surrounded by an atmosphere of negligible density.

D. The adiabatic model, consisting of a mass of gas in adiabatic equilibrium.

The models *A* and *B* are the extreme cases of *C* and *D*. The model *C* goes over into the models *A* and *B* as the atmosphere becomes very small or very large relative to the nucleus. The model *D* goes over into *A* and *B* as γ , the ratio of the specific heats at constant pressure and at constant volume, changes from infinity to 1.2.

If the models are subject to rotation alone, the mechanism of breaking up is quite different for the types *A* and *B*. For model *A* the original spherical form, which the matter must have as a result of its own gravitation if there is no rotation, will first change into a spheroidal form, which, with increasing angular rotational velocity (as the body contracts), changes into an ellipsoidal figure,

the smallest axis of course being parallel to that of rotation. With still higher rotational velocity a furrow will form across a section of the ellipsoid, producing Poincaré's pear-shaped configuration. This configuration is now proved by Jeans to be unstable, and thus, when the furrow once has started, the breaking up of the body into two detached parts takes place.

The model *B*, when subject to rotation, evolves into a lens-shaped figure with sharp edge, from which matter is continually ejected as the velocity is increased. In the more general cases *C* and *D*, one of these two methods of breaking up must occur when the rotational velocity exceeds a certain value.

These two methods of breaking up—fission, and ejection from the equatorial belt—are considered to be the only ones possible in a gaseous body subject to rotation. If tidal forces are present the ways of breaking up are the same as those mentioned before, but the ejection of matter from the equatorial belt is now confined to definite points on the equator.

This theoretical result is in very good harmony with observations of spiral nebulae. The lenticular form is obvious in such nebulae as N. G. C. 3115 and 5866, and many others. Even a very slight gradient in the gravitational field produced by outside bodies would give rise to tidal forces strong enough to force the matter to be ejected from two opposite points, instead of uniformly all around the equator. This condition would produce a spiral nebula with two opposite arms of ejected matter.

Another consequence of the theory is that if a nebula, or gaseous body in general, has shrunk from an approximately isothermal condition to one in which there is a rapid temperature gradient from surface to center, the angular velocity would increase as we pass from the center outwards, supposing of course that the viscosity is insufficient to produce a rotation as a solid body. This gives us a natural explanation of the acceleration of the Sun's rotation at the equator; and also of the slight increase in rotation with distance from the center which can be found in Pease's measurements of the velocities in the *Andromeda* nebula, altho in most cases observation shows that the spiral nebulae rotate as solid bodies.

The theory gives reason to believe that the equatorial breaking up of a contracting nebula is a continuous process, not a periodic one as Laplace and Roche imagined; and further, that the breaking

up is cataclysmic, since the ejected matter itself provides a force tending to increase the rate of ejection of matter. Jeans finds that the nuclei in spiral nebulae are comparable in mass with the Sun, and that a nebula such as that in *Andromeda* may be as massive as the whole galactic system!

The probable result of the disintegration of a spiral nebula, according to Jeans, is a star cluster, the numerous nuclei forming individual stars. Such an evolution is not derived mathematically, to be sure, but is rather an hypothesis which has several observational facts in its favor. The comparability in size and mass between spiral nebulae and star clusters is especially emphasized by Jeans. There are, however, several dissimilarities between these two celestial objects—the star clusters are few in number and have a different distribution in space, and further, the spirals are much more flattened than the star-clusters. The real connection between these two kinds of objects is thus still an open question.

A special chapter has been devoted to the stellar motions in the galactic system. In agreement with all other investigators, Jeans finds that the effect of encounters, and still more of actual collisions of stars, is very slight, owing to the large distance between the stars. It is thus permissible to study the motions of the stars by means of the kinetic theory of gases with collisions left out. Jeans finds now that in a flattened system which has originated out of a rotating nebula, the only steady type of motion is one where the stars are moving in circular orbits around the center of the system. This seems to him to be the interpretation that agrees best with the observational results of Kapteyn's star streams.

A difficult problem is encountered when we look for an explanation of the correlations between spectral type and absolute magnitude, and spectral type and velocity in space. The stars of earlier types have smaller velocities than those of later types, and for stars of the same type, those of high luminosity move more slowly than absolutely fainter stars. An equipartition of energy cannot take place in the present state of the galactic system, the distances between the stars being too great. The suggestion is made that a partial equipartition of energy took place when the system was considerably smaller and the stars more closely packed.

The theory is favorable to the idea of the stars originally becoming hotter by contraction and later on losing heat by radiation. This is in harmony with the evidence found for giants and dwarfs,

the giant M stars being in a state nearest the origin. It is supposed, however, that only the most massive stars attain the B type spectrum.

The author finds it somewhat difficult to explain the evolution of binary stars. A certain lower limit of density is required to account for the breaking up of a star by fission. This limit is set at about one-fourth that of water, and as most giant stars have smaller densities it is difficult to imagine fission due to rotation alone. The dependency of period and the orbital eccentricity of binaries upon spectral type admits, according to Jeans, of no answer as long as the binary is regarded as a self-contained system. Stellar encounters, however, have the tendency to increase the eccentricity, linear dimension, and period of an orbit. After a large number of stellar encounters the eccentricities will group themselves around the mean value $\frac{2}{3}$, while the periods will depend on the mass of the star, being of the order of a year for a star of mass 1.7 times the Sun. In order to reconcile this with the observed distribution of periods and eccentricities we have to assume that the B-type binaries were the last to be born, when the chances of close encounter were rare.

The evolution of the present solar system, which probably is an exception among the stars as the companions are all of very small mass compared with the central body, can only be the result of the passing of a massive star close by the central body, the latter then throwing out jets of matter towards the passing star. Condensations in these jets later on formed the planets.

The book contains many original investigations of a theoretical character by the author, and throws light on numerous problems which are of especial interest to the practical astronomer.